Extratropical Cyclones of the Western U.S.
Major Advances in Prediction and Understanding
Cliff Mass, Atmospheric Sciences

Columbus Day Storm, 1962: The steeple atop historic Campbell Hall, on the Oregon College of Education Campus, Monmouth.
Bottom Line

- Before roughly 1990 most West Coast extratropical cyclones were poorly forecast at any time range.
- After that time, the vast majority were well predicted.
- We now know vastly more about the structure of these storms.
- We know much more about their interactions with West Coast terrain.
The is a lot of talk about the *Perfect Storms* and *Storms of the Century* along the East Coast

- The truth is that the strongest West Coast storms are more intense and damaging.

- Big trees are major “force multipliers” for West Coast midlatitude cyclones.
Wimpy East Coast Trees

Serious West Coast Trees
Some Perspective
Native Americans knew about the great winter storms that struck the Pacific coast ... and had several legends regarding their origin.

The Thunderbird
European explorers appreciated the threat

“The force of southerly storms was evident to every eye; large and extensive woods being laid flat by their power, the branches forming one long line to the North West, intermingled with the roots of innumerable trees, which have been torn from their beds and helped to mark the furious course of their tempests.”

John Meares, 1788, off of Cape Flattery of the Olympics Peninsula
Early settlers learned quickly about the impacts of the great Pacific cyclones.
January 9, 1880 Storm

- Hit northern Oregon and southern Washington toppling tens of thousands of trees.
- Wind gusts were estimated to reach 138 mph on the coast and 70-80 mph in the interior.
- Buildings throughout the Willamette Valley, were damaged or destroyed. Part of the roof of the Oregon State Capital in Salem was blown off.
January 29, 1921

• Hurricane-force winds struck the entire Washington Coast
  – At North Head sustained winds reached 126 mph, with a maximum one-minute wind of 150 mph before the sensor failed.
  – At Tatoosh Island, 150 miles to the north, winds reached 110 mph.
In some areas over 40% of the trees were blown down down.

As a result, this event has become known as the "The Olympic Blowdown Storm"
But these and other storms were overshadowed by the Columbus Day Storm: October 12, 1962

- The strongest Pacific storm to strike the NW since the arrival of European settlers
- Probably the most powerful non-tropical cyclone to hit the lower-48 states in a century. Maybe more.
Extraordinary Impact

• An extensive area, stretching from northern California to southern British Columbia experienced hurricane-force winds, massive treefalls, and power outages.

• Sustained winds reaching 60-70 mph and gusts over 120 mph.

• In Oregon and Washington, 46 died and 317 required hospitalization.

• Flooding and landslides in northern California.

• 955 hPa low moved northward along the coast.
Impacts

• Ten to 15 billion board feet of timber were downed, enough to build a million homes and far greater than the yearly output of the NW forest industry.

• 53,000 homes were damaged, thousands of utility poles were toppled, and the twin 520-ft steel towers that carried the main power lines of Portland were crumpled.
The toppled tower carrying 115,000-volt cables at Barlow Point, two miles west of Longview Bridge on the Columbia River. Bonneville Power Administration photo.
On the state capitol ground in Salem, Oregon, the bronze status, the Circuit Rider was toppled
Columbus Day 1962: At Cape Blanco estimated winds were 150 mph with gusts to 179!
Mt. Hebo Radar Facility:
Gusts exceeding 130 mph

Courtesy: Mark Cole
How good were the Weather Bureau Predictions for the Columbus Day Storm?
The Lead Up

- Forecasters in the Portland and Seattle offices of the Weather Bureau knew there was a fast-moving disturbance out there.
- But the position and amplitude were uncertain.
- The NWP models of the day were predicting a modest system making landfall south of Portland.
October 11th Forecast: No Storm on October 12th!

Seattle Times
As Weather Bureau forecasters analyzed the sparse data over the Pacific for the 5 AM October 12th chart, they realized that the storm was stronger and the threat to the West Coast was substantial.
Jaw-dropping observations

• At 7 AM, the three-hourly reports from a series of radar picket ships off the coast started to come in.

• A ship at 40N, 130 W reported a pressure fall of 22.5 hPa in 3 hours with sustained southeast winds of 50 knots!

• Another picket ship had northwest winds at 80 knots (92 mph), a pressure of 962 hPa, and a pressure fall of 33 hPa in 3 hr.

• A Brazilian ship, 60 miles SW of Cape Blanco, 964 hPa, SE 85 mph

U.S.S Skywatcher
Forecasts were updated to predict a more dangerous storm—hours before it hit.
Could a modern weather prediction model run at high resolution get the forecast right?

- Rick Steed, Research Scientist in the UW Atmospheric Sciences Department, ran the WRF model with full physics and high resolution.
- Initialized the model with the NCEP reanalysis grids.
The Answer: No

Consider a forecast begun the day before (October 11th) at 5 AM.
The Problem?

- Lack of data and poor initializations
- Just a few ship reports offshore.
Major Cyclone Forecast Busts Continued Until Approximately 1990

• ...And then everything changed, almost overnight
• Nearly every major midlatitude cyclone to hit the West Coast has been forecast with some skill up to several days ahead of time.
• Clearly, the advent of more extensive use of satellite data and better models has had impact.
The First Major Forecasting Triumph
Inauguration Day Storm
January 20, 1993
The first major windstorm to be highly skillfully forecast.... But the media and public were not paying attention!
Inauguration Day Storm

• Winds of over 100 mph were observed at exposed sites in the coastal mountains and the Cascades, with speeds exceeding 80 mph along the coast and in the interior of western Washington.

• In Washington State six people died, approximately 870,000 customers lost power, 79 homes and 4 apartment buildings were destroyed, 581 dwellings sustained major damage.
FIG. 7. Mesoscale analyses for (a) 1500 UTC, (b) 1600 UTC, (c) 1700 UTC, (d) 1800 UTC, (e) 1900 UTC, and (f) 2000 UTC 20 January 1993. Contour interval is 2 mb.

Steenburgh and Mass, MWR, 2000
And then another major storm and a highly skillful forecast

December 12, 1995
An Excellent Forecast

And the media went wild!

Dec. 11

Brace yourself for winds

80-mph gusts are possible

SEATTLE TIMES STAFF

The windstorm hitting Western Washington today could rival the ferocity of a Columbus Day 1962 storm that killed eight people, closed hundreds of roads, and caused widespread power outages and millions of dollars in damage, forecasters say.

Gusts of 70 to 80 mph were expected in the Puget Sound area, with the peak of the storm forecast to hit the Seattle area about 5 p.m. High winds are expected to continue into the night.

The low-pressure system built early today off the Oregon Coast, where residents braced for winds as high as 100 mph.

Along the Washington Coast, emergency crews prepared to deal with the possibility of widespread damage. Many schools in Grays Harbor County planned to send students...
A different reaction by society

- Based on the forecasts, Boeing and other major employers sent their staff home early.
- The NWS forecasts had the correct timing---within hours.
- Seattle and Portland NWS forecasters won a NWA Award for their predictions.
And another great success: the December 15, 2006 Chanukah Eve Storm... and many more
In parallel to work on the east coast, there was extensive research to understand explosive cyclogenesis over the eastern Pacific.
A Case Study of Explosive Cyclogenesis in the Eastern Pacific

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Fig. 11. Surface isobaric and frontal analyses: (a) 0600 GMT 13 November and (b) 0000 GMT 14 November 1981. Dashed lines in (b) are isotherms (°C) and shading denotes intermediate temperatures (13°–15°C). Small circles indicate actual or displaced buoy positions. Times of displaced observations are given in parentheses. See text for further explanation.
Numerical Simulation of an Explosively Deepening Cyclone in the Eastern Pacific

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Fig. 4. Sea level pressure (solid) and 1000-500 mb thickness (dashed) for (a) 24 hour forecast for control experiment verifying at 0600 UTC 14 November with fronts subjectively added, and (b) the subjective analysis at the same time reproduced from Reed and Albright (1986). Line of later cross sections indicated by CD.

Fig. 18. (a) Central pressure, beginning at 0000 UTC 13 November, for experiments 1-c. (b) As in (a) but for the 925 mb vorticity maximum.
Field Programs (COAST) and Modeling During the 1990s and Later Revealed Structures Similar to the Keyser-Shapiro Model Off the Pacific Coast

- Strongest winds in the bent-back trough
- But no evidence of evaporatively forced “sting jets”
Chanukah Eve
Storm
Dec. 2006
Strongest Winds With Back-Bent
Scatterometer Winds for the Chanukah Eve Storm Dec. 2006
The Challenges of Pacific Cyclones Also Include Their Interactions with the Substantial Terrain of the West Coast

• This became very evident in February 1979 during the Hood Canal Storm.
• Winds were predicted to reach 40-50 kt, but locally gusted to 120 mph, destroying a 100-million dollar bridge.
Feb. 13, 1979: Winds over 100 kts destroyed the Hood Canal Bridge
Cost to replace: over 100 million dollars
Fig. 4. Surface map for 1600 PST 12 February 1979. Winds are in knots. (A full barb represents 10 kt, a pennant 50 kt.)

Fig. 6. Surface map for 0400 PST 13 February 1979. Storm track is indicated by arrows. Dots give position of center at indicated times.
But why localized 120 knot winds?
Professor Richard Reed found an intense lee-side mesolow.
Do cyclone/terrain interactions produce stronger winds near coastal terrain? Yes, but only when the stability is high.
And certain locations are favored for cyclone/terrain wind enhancement.
Mesoscale Models

High-resolution mesoscale models can get the terrain effects correct much of the time.
A Lot to Be Proud Of…

• Global models (e.g., GFS, ECMWF) are now providing excellent guidance (1-3 days out) for nearly all major cyclones. Often substantial skill 4-7 days ahead.

• We now possess an extraordinarily better understanding of the mesoscale structures of these storms and how they are modified by West Coast terrain.

• High-resolution models appear capable of skillfully predicting many terrain/cyclone interactions.
The End